The association between renal tumour scoring systems and ischemia time during open partial nephrectomy

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Abstract

Objective: To evaluate the association between renal tumour scoring systems and open partial nephrectomy ischemia time.

Methods: A historical cohort of open partial nephrectomy patients at The Ottawa Hospital between 2002 and 2009 was reviewed. Preoperative patient characteristics (age, gender, preoperative renal function, diabetes, hypertension, smoking history, heart disease) and ischemia time were abstracted from medical records. Preoperative computed tomography (CT) images were reviewed and tumours were characterized using three scoring systems: (1) R.E.N.A.L. nephrometry score (radius, exophytic/endophytic properties, nearness of tumour to the collecting system or sinus in millimetres, anterior/posterior, location relative to polar lines); (2) preoperative aspects and dimensions used for anatomic (PADUA) classification; and (3) Centrality index (C index). Patients without preoperative CT and patients treated with laparoscopic partial nephrectomy were excluded.

Results: During the study period, 78 patients met the inclusion criteria. Median R.E.N.A.L. score was 7 (interquartile range [IQR] 5-8), median PADUA score was 8 (IQR 7-10), and mean C index was 3.9 (standard deviation [SD] 2.1). Mean ischemia time was 23.4 (SD 10.8) minutes. Five individual tumour characteristics (diameter, nearness to collecting system, anterior/posterior location, medial/lateral location, and collecting system involvement) were strongly associated with ischemia time ($p < 0.05$). Increased R.E.N.A.L. score (1.5 minutes per unit 95%CI 0.08, 2.9, $p = 0.04$) and PADUA score (2.0 minutes per unit 95%CI 0.5, 3.5, $p = 0.009$) were significantly associated with ischemia time. An increasing C index score was also associated with ischemia time (-1.1 minutes per unit 95%CI -2.2, 0.04, $p = 0.06$), but the association was not statistically significant.

Conclusion: Renal tumour characteristics are associated with ischemia time. The proposed scoring systems are useful descriptors of surgical complexity and should be used when describing partial nephrectomy patients. Prospective evaluation and refinement of scoring systems are required to create an optimized model prior to widespread application.

Introduction

The decision to perform radical versus partial nephrectomy for renal tumours is currently based on the subjective assessment of feasibility and patient preferences. Renal tumour scoring systems are designed to characterize tumours, facilitate cohort comparisons and allow for the prediction of surgical outcomes. Three scoring systems have been proposed and require validation: (1) R.E.N.A.L. nephrometry score (radius, exophytic/endophytic properties, nearness of tumour to the collecting system or sinus in millimeters, anterior/posterior, location relative to polar lines); (2) preoperative aspects and dimensions used for anatomic (PADUA) classification; and (3) Centrality index (C index).[1-3] The R.E.N.A.L. and PADUA systems categorize tumour characteristics and provide an overall score with a high score associated with more complex features. The C index method derives one number that reflects tumour size and distance from the centre of the kidney with a lower score representing tumours that are larger and closer to the kidney centre.

Scoring systems are helpful if they are able to predict outcomes, including technical difficulties of partial nephrectomy, risk of complications (i.e., bleeding, urine leak, need for conversion to radical nephrectomy) and functional/oncologic outcomes (i.e., change in creatinine, risk of recurrence). The original publications and a small number of additional studies have examined some of these outcomes.[1-9] To the best of our knowledge, this is the first study applying all three scoring systems to a cohort of patients treated with open partial nephrectomy to determine which system is most predictive of ischemia time.

We postulated that the individual components and overall scores of the R.E.N.A.L. (Table 1), PADUA and the C index systems are associated with surgical complexity/difficulty. Therefore, if tumour scoring systems predict complexity, we would expect higher R.E.N.A.L. and PADUA scores, and lower C index scores, to be associated with longer ischemia

Table 1. R.E.N.A.L. score incorporating 5 tumour variables: radius, exophytic extent, nearness, anterior/posterior position, polar location

	1 pt	2 pts	3 pts
Radius (maximum diameter in cm)	≤4	5-6	≥7
Exophytic/endophytic properties	≥50%	<50%	Entirely endophytic
Nearness of the tumour to the collecting system or sinus (mm)	≥7	5-6	≤4
Anterior/posterior	No points given. Mass assigned a descriptor of a, p or x.		
Location relative to the polar lines*	Entirely above the upper or below the lower polar line	Lesion crosses polar line	>50% of mass is across polar line (a) or mass crosses the axial renal midline (b) or mass is entirely between the polar line (c)

*Suffix "h" assigned if the tumour touches the main renal artery or vein.

Adapted with permission from Kutikov et al. The R.E.N.A.L. nephrometry score: a comprehensive standardized system for quantitating renal tumor size, location and depth. *J Urol* 2009;182:844-53. http://dx.doi.org/10.1016/j.juro.2009.05.035

time during surgery. The purpose of this study was to apply each scoring system to a cohort of patients who received open partial nephrectomy at our institution and to evaluate the strength of the association between tumour scores and ischemia time.

Methods

Institutional ethics review board approval was obtained to review a historical cohort of patients who underwent open partial nephrectomy for renal tumours between 2002 and 2009 by two surgeons at one tertiary care institution (The Ottawa Hospital, Ottawa, Ontario). Patients without preoperative computed tomography (CT) and patients treated with laparoscopic partial nephrectomy were excluded. Abstracted patient characteristics, including age, gender, pre-/postoperative serum creatinine, diabetes, hypertension, smoking history and heart disease, were recorded. Ischemia time was prospectively documented during each procedure. All preoperative CT scans of the abdomen and pelvis were reviewed by two independent physicians (LL, DD). Tumour characteristics and scores were recorded by applying the criteria outlined by each renal tumour scoring systems (R.E.N.A.L., PADUA, C index).[1-3]

Predictor variables and scoring systems

The R.E.N.A.L. and PADUA systems are composite scores that describe renal masses in a quantifiable way. They incorporate tumour diameter, tumour location within the kidney (e.g., anterior/posterior, medial/lateral, polar/non-polar) and tumour association with other structures (e.g., renal sinus or collecting system). Although the R.E.N.A.L. and PADUA systems have many similarities, they differ in their incorporation and definition of several variables. Although both systems propose that the polar location is an important variable, they stratify tumour polarity differently. The C index score is derived from a series of measurements made on cross-sectional imaging. It describes tumour size and position relative to the centre of the kidney.

Outcome variables

Each scoring system was evaluated for their associations with ischemia time (primary outcome) and perioperative change in serum creatinine concentration (secondary outcome). Ischemia time was extracted from the operative record and refers to the duration of time required for tumour excision and renal reconstruction; it was used as an indicator for surgical complexity. Change in renal function was assessed using standardized laboratory assays by measuring the difference in serum creatinine concentration preoperatively compared to 3 months postoperatively.

Statistical analysis

Inter-rater reliability was assessed to quantify the agreement between reviewers for each tumour score component using Pearson and Kappa analytic techniques, as appropriate. Univariate linear regression analysis determined the association between scoring systems, individual tumour characteristics, and clinical characteristics with ischemia time and perioperative change in creatinine. A multivariable linear regression model was created to evaluate the independent associations between each tumour component and ischemia time or perioperative change in creatinine. Components that are not incorporated into the overall numerical score, such as the anterior/posterior location (R.E.N.A.L., PADUA) and hilar association (R.E.N.A.L.), were evaluated independently, but were not included in the multivariable analysis. Tumour predictor variables for R.E.N.A.L. and PADUA were treated categorically. C index characteristics/scores and overall R.E.N.A.L. and PADUA scores were treated as continuous variables.

To compare tumour scoring models, the coefficient of determination (r^2) was calculated. The r^2 was determined for multivariable models that incorporated the overall score (R.E.N.A.L., PADUA or C index) and clinical information (age, sex, preoperative creatinine, diabetes, smoking history, hypertension and heart disease). The r^2 value indicates what proportion of the variability in outcome (ischemia time or

change in creatinine) is explained by the scoring models and clinical information combined.

Results

A total of 110 open partial nephrectomies were performed by two surgeons at The Ottawa Hospital from 2002 to 2009. After excluding patients without available preoperative CT imaging (n = 32), 78 were reviewed. Of the 78, 6 did not have documented ischemia times and were excluded from analyses evaluating predictors of ischemia time. We tallied their clinicopathological characteristics (Table 2).

Tumour characteristics and inter-rater agreement

Inter-rater agreement was good for all tumour characteristics and scoring systems. C index had a higher degree of agreement compared to R.E.N.A.L. or PADUA (Table 3).

Ischemia time

For the primary analysis, the associations between scoring systems and ischemia time were evaluated (Table 4). Both R.E.N.A.L. and PADUA scores were significantly associated with ischemia time. For every increase in R.E.N.A.L. score of 1, an increase in average ischemia time of 1.5 minutes was observed (95%CI [confidence interval] 0.08, 2.9, $p = 0.04$). For PADUA, the magnitude of association was larger. An increase in an overall PADUA score of 1 was associated with an additional 2.0 minutes of ischemia time (95%CI 0.5, 3.5, $p = 0.009$), on average. The overall C index score was also associated with ischemia time, for every increase in C index unit of 1, a decrease of 1.1 minutes (95%CI -2.2, 0.04, $p = 0.06$) was observed; however this association was not statistically significant in this series. The r^2 value for each scoring system model were R.E.N.A.L. (13.5%), PADUA (17.1%) and C index (13.4%), indicating that none of the models explained a high proportion of ischemia time variability.

On univariate analysis, no association was found between any of the clinical characteristics and ischemia time (Table 2). Strong associations were observed between the following predictor variables and ischemia time: diameter (C index), nearness (R.E.N.A.L.), anterior/posterior location (R.E.N.A.L., PADUA), collecting system involvement (PADUA),and medial/lateral location (PADUA) (Table 4). On average, for each additional centimetre of tumour diameter, an additional 1.9 minutes (95%CI 0.2, 3.6, $p = 0.04$) of ischemia time was required. If a tumour was ≤4 mm from the renal sinus/collecting system, it was associated with 6.1 minutes more ischemia time (95%CI 1.0, 11.3, $p = 0.02$) compared to a tumour ≥7 mm from the sinus/collecting system. Tumours associated with the collecting system according to the PADUA system were associated with 5.4 minutes more ischemia time than those that were not (95%CI -10.7, 0.0, $p = 0.05$). On average, medially located tumours were associated with 7.9 minutes (95%CI 3.1, 12.7, $p = 0.002$) more ischemia time than lateral tumours. Tumours in posterior locations

Table 2. Patient, operative and tumour characteristics; association between clinical characteristic and ischemia time and perioperative change in creatinine

Demographics	n (SD or %)	Ischemia time		Change in creatinine	
		Coefficient 95%CI	*p* value	Coefficient 95%CI	*p* value
Age (years)	61.0 (13.5)	0.1 (-0.06, 0.3)	0.2	0.4 (0.05, 0.8)	0.03
Sex		0.06 (-5.4, 5.5)	1.0	6.6 (-5.6, 18.8)	0.3
Male	55 (70.5%)				
Female	23 (29.5%)				
Preoperative creatinine	100.6 (40.3)	0.04 (-0.02, 0.1)	0.2	0.07 (-0.07, 0.2)	0.3
Diabetes	13 (16.7%)	1.3 (-8.9, 5.4)	0.7	-5.9 (-20.9, 9.1)	0.3
Hypertension	39 (50.0%)	-4.1 (-9.0, 0.8)	0.1	-4.9 (-16.1, 6.2)	0.4
Heart disease	25 (32.1%)	2.4 (-2.9, 7.6)	0.4	-6.4 (-18.3, 5.6)	0.3
Smoking history	48 (61.5%)	-1.7 (-6.8, 3.4)	0.5	-7.3 (-18.7, 4.1)	0.2
Kidney					
Right (%)	36 (46.2%)				
Left (%)	42 (53.9%)				
Estimated blood loss (cc)	351 (617)				
Ischemia time (minutes)	23.4 (10.8)				
% Positive margin	3 (3.9%)				
Tumour pathology					
Malignant (%)	60 (76.9%)				
Benign (%)	18 (23.1%)				
Tumour diameter (cm)	2.7 (1.6)				

SD: standard deviation; CI: confidence interval.

Table 3. Renal tumour characteristics and inter-rater agreement calculated using Kappa or Pearson's tests for each score

Variable	Value	Inter-rate agreement coefficient
NEPHROMETRY SCORE		
Diameter (cm)		0.9 (0.7,1.0)
≤4	66 (84.6%)	
5-6	12 (15.4%)	
≥7	0 (0%)	
Exophytic/endophytic		0.5 ($p < 0.0001$)
≥50% exophytic	28 (35.9%)	
<50% exophytic	48 (61.5%)	
Entirely endophytic	2 (2.6%)	
Nearness (mm)		0.7 (0.6,0.8)
≥7	37 (47.4%)	
5-6	9 (11.5%)	
≤4	32 (41.0%)	
Polar location (relative to polar lines)		0.8 (0.7,0.9)
Entirely above polar line	34 (43.6%)	
Crosses polar line	20 (25.6%)	
>50% across polar line or crosses axial midline or entirely between polar lines	24 (30.8%)	
Anterior posterior		0.6 (0.5,0.7)
Anterior	33 (42.3%)	
Posterior	31 (39.7%)	
Could not assess	14 (17.9%)	
Overall		0.6 (0.5,0.7)
Median	7 (IQR 5-8)	
4	10 (12.8%)	
5	11 (14.1%)	
6	16 (20.5%)	
7	18 (23.1%)	
8	9 (11.5%)	
9	12 (15.4%)	
10	2 (2.6%)	
Risk group		0.5 (0.4,0.7)
Low	37 (47.3%)	
Moderate	39 (50.0%)	
High	2 (2.6%)	
PADUA SCORE		
Diameter (cm)		0.9 (0.7,1.0)
≤4	66 (84.6%)	
5-6	12 (15.4%)	
≥7	0 (0%)	
Polar location		0.8 (0.6,0.9)
Superior/inferior	32 (41.0%)	
Middle	46 (59.0%)	
Exophytic		0.5 ($p < 0.0001$)
≥50% exophytic	28 (35.9%)	
<50% exophytic	48 (61.5%)	
Entirely endophytic	2 (2.6%)	
Renal rim		0.8 (0.7,0.9)
Lateral	47 (60.2%)	
Medial	31 (39.7%)	
Renal sinus		0.7 (0.6,0.9)
Not involved	49 (62.8%)	
Involved	29 (37.2%)	
Urinary collecting system		0.5 (0.3,0.7)
Not involved	55 (70.5%)	
Involved	23 (29.5%)	
Face		0.6 (0.5,0.7)
Anterior	33 (42.3%)	
Posterior	31 (39.7%)	
Could not access	14 (17.9%)	
Overall score		
Median	8 (IQR 7-10)	
6	7 (9.0%)	
7	15 (19.2%)	
8	26 (33.3%)	
9	8 (10.3%)	
10	9 (11.5%)	
11	12 (15.4%)	
12	1 (1.3%)	
13	0 (0%)	
C Index		
Horizontal distance - x (cm)	2.7 (1.0)	0.9 ($p < 0.0001$)
Vertical distance - y (cm)	2.8 (1.8)	0.9 ($p < 0.0001$)
Diameter	2.7 (1.4)	0.9 ($p < 0.0001$)
C	4.2 (1.2)	0.9 ($p < 0.0001$)
C index	3.9 (2.1)	0.9 ($p < 0.0001$)

were associated with an average of 6.1 minutes (95%CI 0.8, 11.4, $p = 0.03$) more ischemia time than anterior tumours. Other predictor variables were associated with ischemia time, however these were not statistically significant (Table 4). We also tallied the independent associations of score components with ischemia time (Table 5). C index diameter and PADUA medial/lateral location were the only components independently associated with ischemia time in a statistically significant fashion when controlling for the other components of the respective scoring systems ($p < 0.05$).

Change in serum creatinine

None of the overall system scores were statistically associated with perioperative change in creatinine (Table 4). The proportion of perioperative change in creatinine explained by each scoring system was low: R.E.N.A.L. ($r^2 = 7.9\%$), PADUA ($r^2 = 8.0\%$) and C index ($r^2 = 7.9\%$). Patient age,

Table 4. Unadjusted associations between tumour scores and ischemia time or perioperative change in creatinine

Variable	Univariate analysis			
	Ischemia time		Change in creatinine	
	Coefficient (95%CI)	*p* value	Coefficient (95%CI)	*p* value
NEPHROMETRY score				
Diameter (cm)				
≤4 vs. 5-6	-5.8 (-12.5, 0.9)	0.08	-17.4 (-32.5, -2.4)	0.02
Exophytic/endophytic				
≥50% exophytic vs. <50% exophytic	-0.06 (-5.3, 5.2)	1.0	-0.5 (-12.3, 11.3)	0.9
≥50% exophytic vs. Entirely endophytic	4.4 (-17.9, 26.6)	0.7	-18.5 (-54.7, 17.7)	0.3
<50% exophytic vs. Entirely endophytic	4.4 (-17.7, 26.5)	0.7	-18.0 (-53.7, 17.8)	0.3
Nearness (mm)				
≥ 7 vs. 5-6	0.4 (-7.4, 8.2)	0.9	-1.2 (-19.4, 17.0)	0.9
≥ 7 vs. ≤4	-6.1 (-11.3, -1.0)	0.02	-9.8 (-21.6, 2.0)	0.1
5-6	-6.6 (-14.5, 1.4)	0.1	-8.6 (-27.1, 9.8)	0.4
Polar location (relative to polar lines)				
Entirely above polar line vs. Crosses polar line	-2.2 (-8.5, 4.0)	0.5	-3.7 (-17.6, 10.3)	0.6
Entirely above polar line vs. >50% across polar line or crosses axial midline or entirely between polar lines	-2.3 (-8.2, 3.7)	0.4	4.3 (-8.9, 17.5)	0.5
Crosses polar line vs. >50% across polar line or crosses axial midline or entirely between polar lines	-0.03 (-6.8, 6.7)	1.0	8.0 (-7.0, 23.0)	0.3
Anterior posterior				
Anterior vs. Posterior	-6.1 (-11.4, -0.8)	0.03	-1.2 (-13.7, 11.2)	0.8
Anterior vs. Could not assess	-6.5 (-13.4, 0.4)	0.06	-4.0 (-19.8, 11.9)	0.6
Posterior vs. Could not assess	-0.4 (-7.4, 6.5)	0.9	-2.7 (-18.7, 13.3)	0.7
Overall score	**1.5 (0.08, 2.9)**	**0.04**	**2.2 (-1.1, 5.4)**	**0.2**
Risk group				
Low vs. Moderate	-3.5 (-8.6, 1.5)	0.2	0.3 (-10.5, 11.2)	1.0
Low vs. High	-6.6 (-22.3, 9.0)	0.4	-49.3 (-83.6, -14.9)	0.006
Moderate vs. High	-3.1 (-18.7, 12.5)	0.7	-49.6.0 (-83.9, -15.3)	0.005

categorical tumour diameter (R.E.N.A.L. and PADUA) and risk group (R.E.N.A.L.) were the only predictor variables that were associated with perioperative change in creatinine in univariate analysis in a statistically significant manner (Table 4). In multivariable analysis, adjusting for the other components of each respective scoring system, only the C index defined diameter was significantly associated with perioperative change in creatinine ($p < 0.05$) (Table 5).

Discussion

The objective of partial nephrectomy is to achieve equivalent cancer control to radical nephrectomy while preserving renal function.[10-13] Partial nephrectomy is the more complex surgical procedure and is associated with increased risk of perioperative complications compared to radical nephrectomy.[14,15] Therefore, patients are offered partial nephrectomy if the perceived benefits outweigh the subjective risk. Until recently, no objective criteria were used to define the complexity of a renal tumour. Thus, reported benefits and risks of partial nephrectomy for individual patients could be over or underestimations of the truth. To address this deficiency in objective criteria, three renal tumour scoring systems have been proposed: R.E.N.A.L., PADUA and C index.

Quantifying case complexity is not easy. We hypothesized that ischemia time is a good representative of case complexity since less complex cases should require less ischemia time to perform the tumour removal and kidney reconstruction compared to more complex cases. We observed that overall PADUA and R.E.N.A.L. scores were associated with ischemia time. As the scores increased (indicating more complex tumours), the ischemia time increased. For every increase in an overall PADUA score of 1, the ischemia time increased by an average of 2.0 minutes (95%CI 0.5, 3.5, $p = 0.009$. For every increase in a R.E.N.A.L. score of 1, the ischemia time increased by an average of 1.5 minutes (95%CI 0.08, 2.9, $p = 0.04$). For every increase in C index of 1 (indicating either a smaller tumour and/or a tumour more distant from the centre of the kidney), the ischemia time decreased by an average of 1.1 minutes (95%CI -2.2, 0.04, $p = 0.06$). However, the r^2 value revealed that although the scoring systems were predictive of ischemia time, they account for only a small proportion of the ischemia time variability.

Table 4. Cont'd

Variable	Univariate analysis			
	Ischemia time		Change in creatinine	
	Coefficient (95%CI)	*p* value	Coefficient (95%CI)	*p* value
PADUA score				
Diameter (cm)				
≤4 vs. 5-6	-5.8 (-12.5, 0.9)	0.08	17.4 (-32.5, -2.4)	0.02
Polar location				
Superior/inferior vs. Middle	-1.5 (-6.6, 3.6)	0.6	-1.2 (-10.2, 12.5)	0.8
Exophytic rate				
≥50% exophytic vs. <50% exophytic	-0.06 (-5.3, 5.2)	1.0	-0.5 (-12.3, 11.3)	0.9
≥50% exophytic vs. Entirely endophytic	4.4 (-17.9, 26.6)	0.7	-18.5 (-54.7, 17.7)	0.3
<50% exophytic vs. Entirely endophytic	4.4 (-17.7, 26.5)	0.7	-18.0 (-53.7, 17.8)	0.3
Renal rim				
Lateral vs. medial	-7.9 (-12.7, -3.1)	0.002	1.5 (-9.9, 13.0)	0.8
Renal sinus				
Not involved vs. involved	-4.2 (-9.3, 0.9)	0.1	-7.5 (-19.0, 4.0)	0.2
Urinary collecting system				
Not involved vs. Involved	-5.4 (-10.7, 0.0)	0.05	-11.0 (-23.1, 4.0)	0.07
Face				
Anterior vs. posterior	-6.1 (-11.4, -0.8)	0.03	-1.2 (-13.7, 11.2)	0.8
Anterior vs. Could not assess	-6.5 (-13.4, 0.4)	0.06	-4.0 (-19.8, 11.9)	0.6
Posterior vs. Could not assess	-0.4 (-7.4, 6.5)	0.9	-2.7 (-18.7, 13.3)	0.7
Overall score	**2.0 (0.5, 3.5)**	**0.009**	**2.6 (-0.9, 6.0)**	**0.1**
C index				
Horizontal distance - x (cm)	-0.8 (-3.4, 1.8)	0.5	-5.3 (-10.8, 0.2)	0.06
Vertical distance - y (cm)	-0.4 (1.8, 1.0)	0.6	1.6 (-1.5, 4.7)	0.3
Diameter	1.9 (0.2, 3.6)	0.04	3.2 (-0.7, 7.1)	0.1
C	-0.6 (-2.8, 1.6)	0.6	-0.6 (-5.3, 4.9)	0.8
C index	-1.1 (-2.2, 0.04)	0.06	-1.3 (-3.9, 1.3)	0.3

The results of this study are consistent with previously reported series of open, laparoscopic and robotic partial nephrectomies in which PADUA, R.E.N.A.L. or C Index scores were applied.[3,6-9] To the best of our knowledge, this is the first study comparing all three scoring systems with ischemia time in patients undergoing open surgery. Other authors have stratified R.E.N.A.L. and PADUA scores into risk groups predicting ischemia time; our data revealed similar associations, however, these were not statistically significant.[7,8]

Systems to describe renal tumours are needed and the three proposed scoring systems appear to improve the current standard. The proposed models quantify tumour characteristics and have some value in predicting surgical complexity. However, these data would suggest that further validation and refinement are needed prior to widespread acceptance.[4-7] The R.E.N.A.L. score was derived based on what the authors felt were important tumour characteristics rather than with statistical validation against an important outcome.[2] The PADUA classification and C index methods compared their components to clinical outcomes in the initial publications, but further study is required to determine if these components are optimally defined and weighted.[1,3] For example, although tumour location and collecting system involvement are associated with ischemia time, perhaps one of these components is significantly more important than the other. This needs to be examined and reflected before a definitive scoring system is universally applied.

We found each of the scoring systems easy to use, as inter-rater agreement was good. C index had the least inter-rater variation, likely due to fewer individual components and measurements. Clearly, renal tumour scoring systems should be simple to apply and should eliminate extraneous components that are not consistently predictive of clinically important outcomes.

Several limitations should be considered when interpreting these data. This study does not evaluate the ability of the tumour scoring systems to evaluate the largest and most complicated tumours, since the cohort did not contain tumours >7 cm in size. Therefore, the utility of the scoring systems for the most complex tumours is yet to be defined. In addition, a larger sample size would be required to detect

Table 5. Adjusted associations between scoring system components and ischemia time or peri-operative change in creatinine.

Variable	Multivariable analysis			
	Ischemia time		Change in creatinine	
	Coefficient (95%CI)	*p* value	Coefficient (95%CI)	*p* value
NEPHROMETRY score				
Diameter (cm)				
≤4 vs. 5-6	-0.2 (-9.5, 8.9)	1.0	-18.9 (-39.7, 1.9)	0.07
Exophytic/Endophytic				
≥50% exophytic vs. <50% exophytic	0.8 (-5.0, 6.7)	0.8	-1.7 (-14.8, 11.3)	0.8
≥50% exophytic vs. Entirely endophytic	9.5 (-13.6, 32.6)	0.4	-22.7 (-61.1.3, 15.6)	0.2
<50% exophytic vs. Entirely endophytic	8.7 (-13.9, 31.2)	0.4	-21.0 (-57.5, 15.4)	0.3
Nearness (mm)				
≥ 7 vs. >4 <7	0.5 (-7.8, 8.8)	0.9	-2.3 (-21.0, 16.4)	0.8
≥ 7 vs. ≤4	-6.3 (-13.1, 0.6)	0.07	-1.8 (-17.2, 13.6)	0.8
>4 <7 vs. ≤4	-6.8 (-15.8, 2.2)	0.1	0.5 (-19.8, 20.8)	1.0
Polar location (relative to polar lines)				
Entirely above polar line vs. Crosses polar line	-1.8 (-8.5, 4.9)	0.6	0.9 (-13.9, 15.7)	0.9
Entirely above polar line vs. >50% across polar line or crosses axial midline or entirely between polar lines	-1.8 (-8.0, 4.4)	0.6	8.1 (-5.5, 21.6)	0.2
Crosses polar line vs. >50% across polar line or crosses axial midline or entirely between polar lines	-0.01 (-7.0, 7.0)	1.0	7.2 (-8.3, 22.6)	0.4
PADUA score				
Diameter (cm)				
≤4 vs. 5-6	-3.6 (-12.5, 5.4)	0.4	-20.2 (-40.2, -0.5)	0.06
Polar location				
Superior/inferior vs. Middle	-1.5 (-6.5, 3.5)	0.5	2.4 (-8.7, 13.7)	0.7
Exophytic rate				
≥50% exophytic vs. <50% exophytic	-1.3.6 (-6.8, 4.3)	0.7	-4.1 (-17.0, 8.7)	0.5
≥50% exophytic vs. Entirely endophytic	8.4 (-15.7, 32.6)	0.5	-33.4.0 (-72.8, 5.9)	0.09
<50% exophytic vs. Entirely endophytic	9.7 (-13.7, 33.1)	0.4	-29.3 (-66.8, 8.2)	0.1
Renal rim				
Lateral vs. Medial	-7.6 (-13.0, -2.3)	0.006	6.2 (-6.1, 18.5)	0.3
Renal sinus				
Not involved vs. Involved	-0.3 (-10.7, 10.2)	1.0	14.2 (-9.1, 37.5)	0.2
Urinary collecting system				
Not involved vs. Involved	-0.5 (-11.3, 10.4)	1.0	-15.5 (-39.2, 8.3)	0.2
C index				
Horizontal distance - x (cm)	-4.6 (-9.9, 0.7)	0.09	-0.1 (-11.8, 11.6)	1.0
Vertical distance - y (cm)	-3.4 (-8.3, 1.6)	0.2	7.3 (-3.8, 18.3)	0.2
Diameter	2.1 (0.3, 3.9)	0.02	4.7 (0.7, 8.6)	0.02
C	3.9 (-3.3, 11.1	0.3	-10.6 (-26.5, 5.4)	0.2

small differences in tumour scoring systems and individual component associations. Serum creatinine is a suboptimal method of measuring perioperative change in renal function; future studies using more accurate measurements of renal function are required prior to making conclusions regarding the association of scoring systems and perioperative change in renal function.

Ideally, to develop the most efficient predictive model, various tumour characteristics would be independently evaluated to determine associations with important clinical outcomes and the resultant model would be prospectively validated in surgical patients. In current scoring systems, the choice of components, stratification methods (categorical vs. continuous) and the method of weighting require further refinement. For example, the point designation for the component nearness (R.E.N.A.L.) stratifies tumours from ≥7, 5-6 and ≤4 mm from the collecting system/sinus for simplicity, not because these categories are associated with different outcomes. Also, if one predictor variable (e.g., tumour diameter) is more highly associated with outcomes than other

components, it may warrant increased influence over the overall scoring system than less important components. This series found that the anterior/posterior location (R.E.N.A.L., PADUA) was significantly associated with ischemia time, yet neither system incorporates this variable into the numerical score, only a qualitative descriptor is used, which renders the clinical application more cumbersome. Finally, the purpose of ischemia time in this study was to determine the complexity of surgical resection. While renal ischemia time is likely the easiest outcome to measure and analyze, the clinical importance of small changes in ischemia times (adjusting for tumour characteristics) is yet to be defined.

Conclusion

Both R.E.N.A.L. and PADUA scores are significantly associated with ischemia time. Some individual renal tumour characteristics are also associated with ischemia time. The proposed scoring systems are useful descriptors of tumour complexity, but they require further refinement prior to widespread use. The degree of variability of ischemia time that is explained by current scoring systems is low; therefore, we need further exploration of models that may be more predictive of ischemia time.

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